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PROCEEDINGS OF THE SOUTHEAST FISHERIES SCIENCE CENTER SHRIMP RESOURCE REVIEW

BY

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Global Warming: Effects of Sea Level Rise on Shrimp Fisheries

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Abstract

Central Hypothesis

Sea level rise from global warming will first increase and then decrease shrimp fisheries through modification of wetland habitats.

Subhypothesis:

Sea level rise effects on wetland-dependent shrimp production can be predicted by modelling coastal systems with differing rates of submergence.

Subsidence in the northwestern Gulf of Mexico reproduces effects of sea level rise on the relationship between wetland change and shrimp productivity.

Sea level induced changes to shrimp fisheries will be modified regionally according by differences in wetland types, tides, and geology.

Projected Sea Level Rise

Sea level rise is one of the inevitable consequences expected from global warming in the next century. An increase in global temperature will cause eustatic rise of sea level by melting land-based glaciers and expanding water volume of the ocean. If the average temperature increases by 3°C by the year 2050 and remains constant thereafter, the Intergovernmental Panel on Climate Change estimates that sea level will probably rise at least 66 cm by 2100, a rate 3 to 6 times faster than over the past hundred years.

Effect of Sea Level Rise on Wetland Accessibility for Consumers

High rates of sea level rise cause intertidal wetlands to drown. In the process of drowning, which may take years to decades, habitat conditions change. As marshes drown, for example, initial conditions cause tidal inundation, marsh edge and marsh area to increase. Area expands due to residual drowning plants seaward and upland encroachment landward. Another notable change is that waterways in drowning marshes become more numerous and the geomorphic appearance becomes more reticulated. These changes cause marsh habitat to become progressively more effective for juveniles of shrimp species. The improvement in growth and survival rates of these and other species may lead to greater fishery productivity.

Greater Fishery Production Due to Wetland Submergence

Marsh wetlands in the northwestern Gulf of Mexico have submergence rates that are similar to those predicted for SL rise (1 cm per year) in the next century. Moreover, in the past three decades (since 1960) submergence rates have increased (rates are still within the range of long-term variability). The question is whether shrimp production in the northwestern Gulf of Mexico can be related to changing water levels. According to our hypothesis, if initial stages of accelerated water level rise exist, wetland dependent fishery production should increase. NMFS landings records show that offshore yields of brown shrimp and white shrimp as well as menhaden fisheries in the

Gulf of Mexico have indeed increased significantly since 1960. By applying virtual population analyses (VPAs), we can show that the greater landings of these fisheries are supported by increases in recruitment to fishable stocks. The increases in recruitment are attributed to the improved functions of drowning marshes as nursery habitat for fishery juveniles.

Effect of Long-term Habitat Loss

High fishery yields are not indefinitely sustainable under present subsidence conditions nor under conditions of predicted greater sea level rise. As drowning marshes convert to open water habitats and run out of uplands to migrate onto, the high yields of estuarine-dependent species will disappear or shift elsewhere. In a new model, using EPA's wetland loss model and NMFS data, Dr. Richard Park (Indiana University) has predicted sequential changes in coastal wetlands and the related long-range changes in productivity of brown shrimp. As a case, most of the Grand Chenier wetlands of Louisiana convert to open water as water level rises to 1 meter. Corresponding to this loss of wetland area, shrimp production turns significantly downward over the long term. By extending the model, preliminary estimates of losses of long range yields of brown shrimp, related to predicted sea level rise in the Gulf, have been set at as much as 50%.

Regional Differences

The impact of sea level rise on wetlands will be regionally modified through tides, geology and other factors. The influence of such factors are not yet enough understood, but evidence currently exists of differences in marsh functions to fisheries between regions. As an example, roughly one half of the salt marshes in the SE region occur along the U.S. Atlantic coast. Compared to NW Gulf marshes, these are relatively less accessible because of higher elevations (negligible subsidence), larger, more frequent tides, and lower densities of drainage channels. Given these conditions, production characteristics of shrimp (and other estuarine-dependent fisheries) of the SE Atlantic should be lower than in the Gulf. Indeed, it can be shown that brown shrimp and white shrimp landings of the SE Atlantic are relatively low, and that yields have not changed significantly in recent decades.

Summary

In summary four main points emerge:

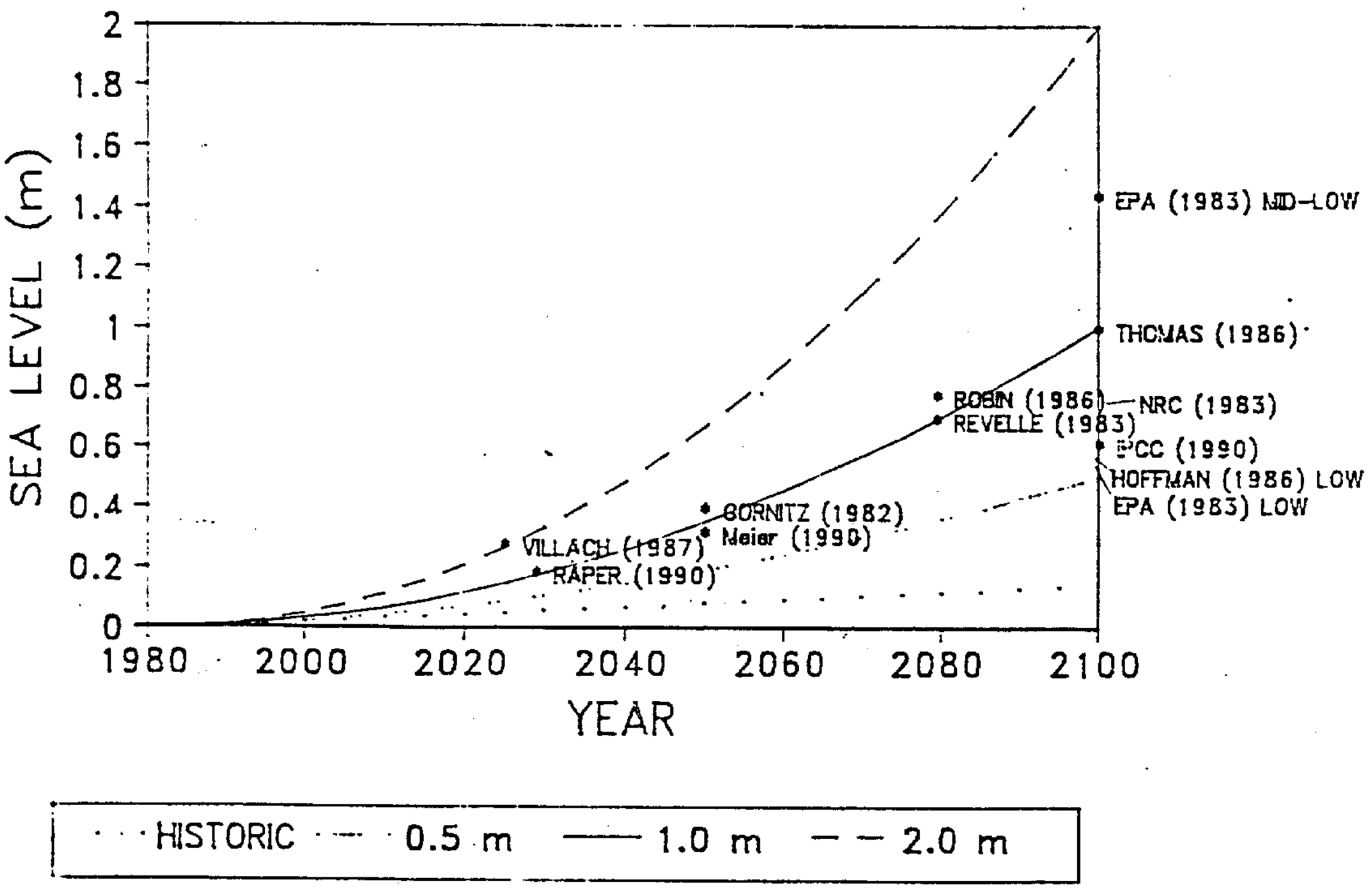
1) Subsidence can be used as a surrogate to predict effects of sea level rise on wetland functions and fisheries production;

2) Responses of shrimp fisheries to wetland area and accessibility changes caused by sea level rise are predictable;

3) Effects of sea level rise on shrimp fisheries are modified geographically by tides, geology and wetland types; and

4) Responses of wetland habitat and shrimp production change to sea level rise can be modelled on basin, regional and global scales.

If sea level rise accelerates, landings of east coast shrimp and other estuarine-dependent species are predicted to follow a pattern of increases similar to those seen in the subsiding NW Gulf. Both regions eventually decline in estuarine-dependent fisheries production due to habitat loss. These observations have relevance to estuarine systems worldwide, meriting investigation both from ecosystems and human impacts perspective (Figs. 31-40).



ure 31. Predictions of sea level rise over the next century taken from the literature.

Gulf of Mexico and SE Atlantic Fisheries Dependent on Marsh Habitat:

1) Brown Shrimp

2) White Shrimp

3) Blue Crab

4) Scuthern Flounder

5) Spotted Seatrout

6) Red Drum

7) Menhaden

Sea Level Rise Promotes Utilization of Marshes by:

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1) Expanding Estuarine Area

2) Extending Duration of Flooding

3) Increasing Marsh Edge

Responses of Marshes to Sea Level Rise

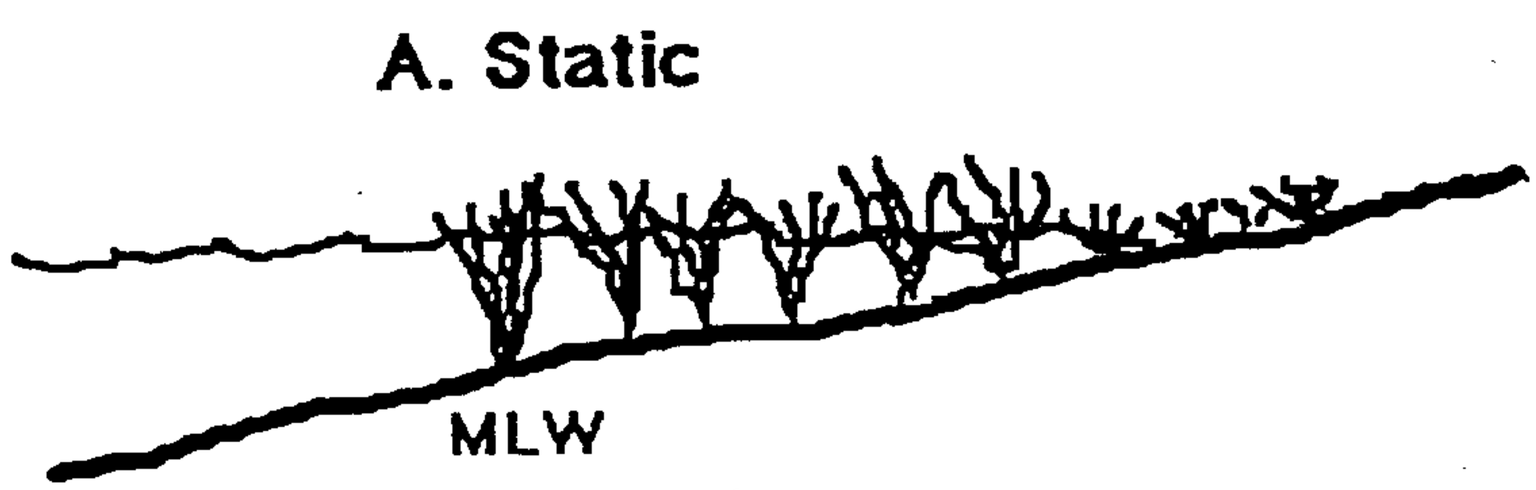
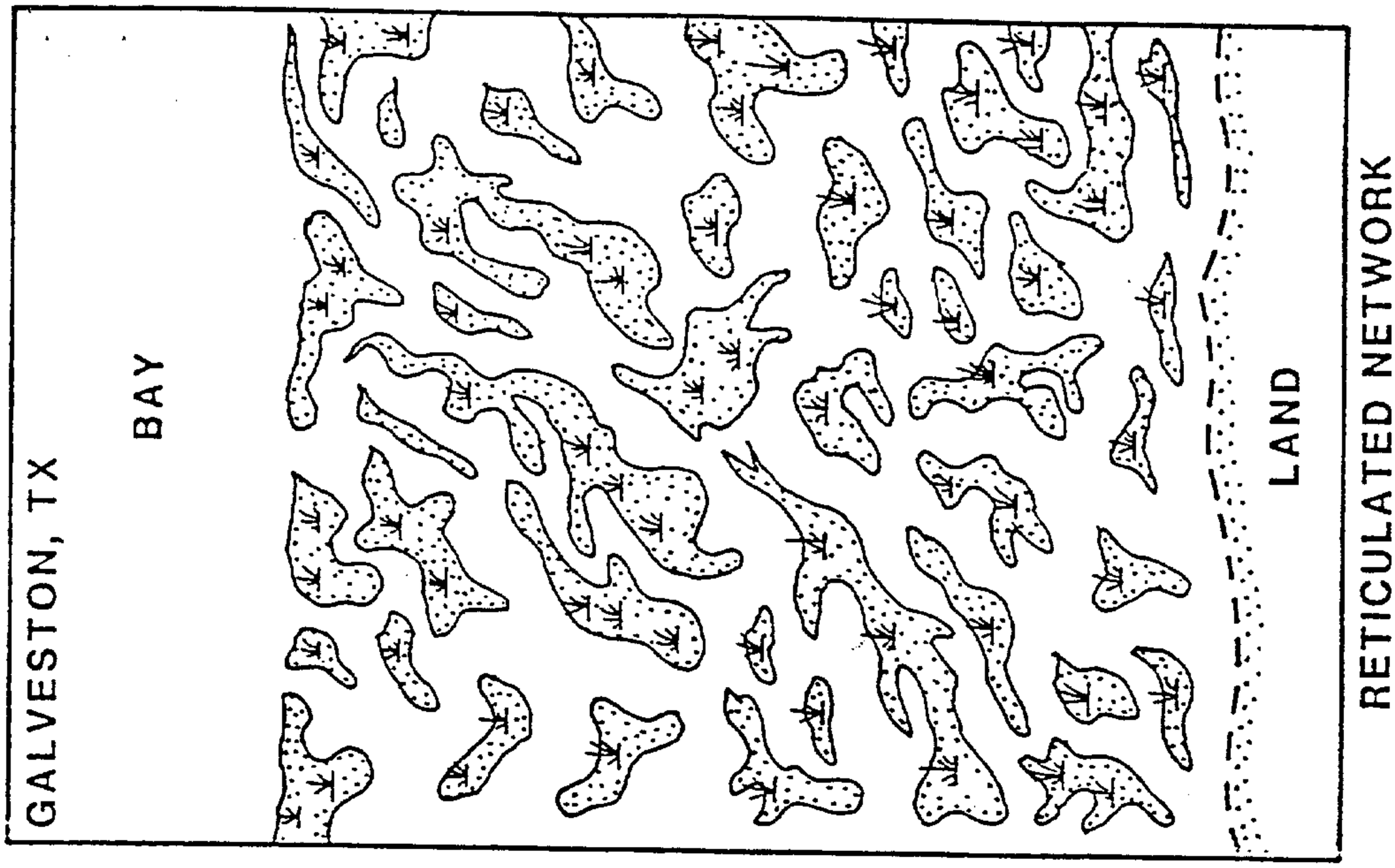


Figure 32. Progression of changes in salt marsh area as accelerated sea level rise affects inundation of coastal regions.



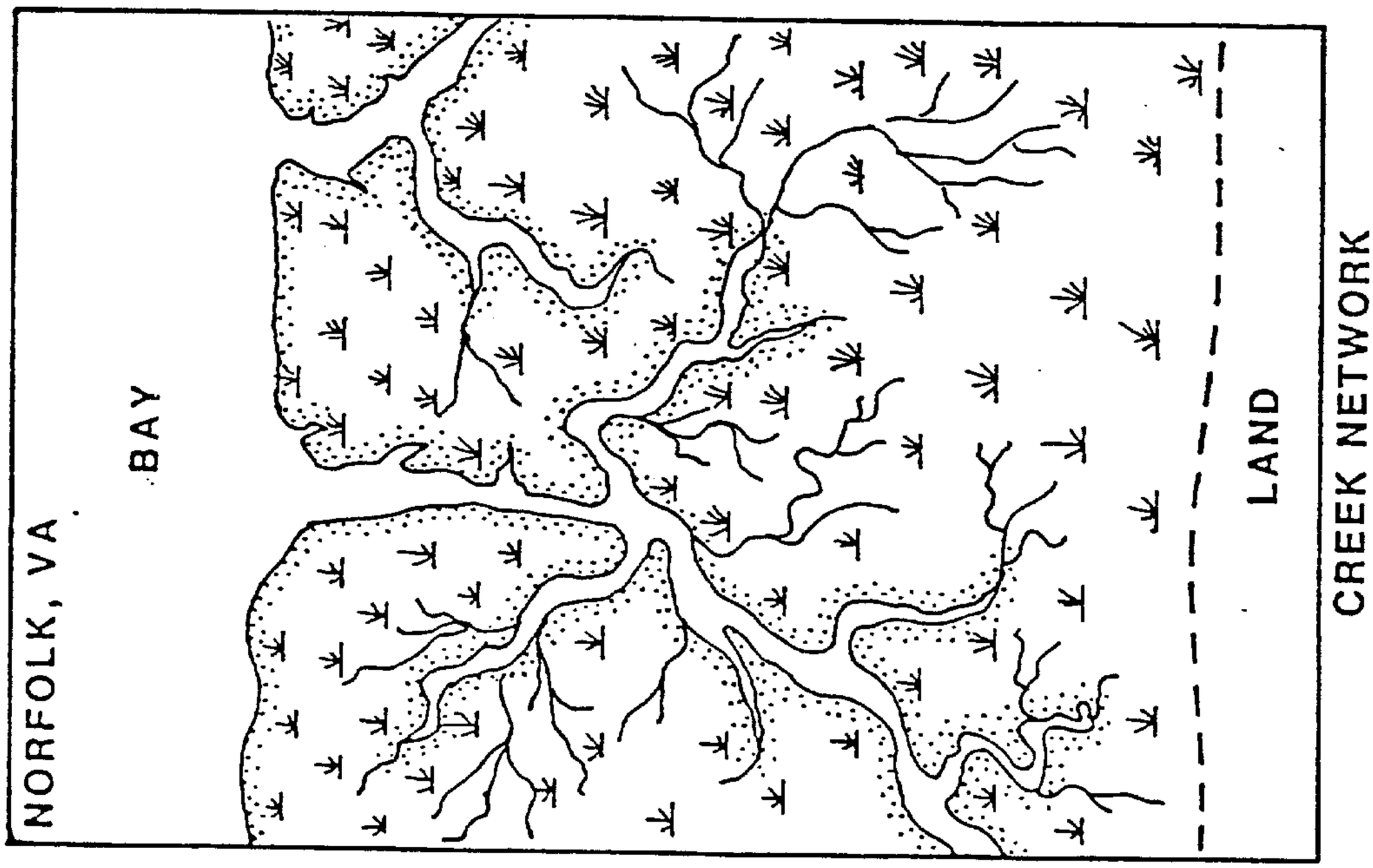


Figure 33. Differences in geometry of static (dendritic creek network) versus drowning (reticulated network) marsh surfaces.

How will long-term sea level rise affect wetlands and fisheries?

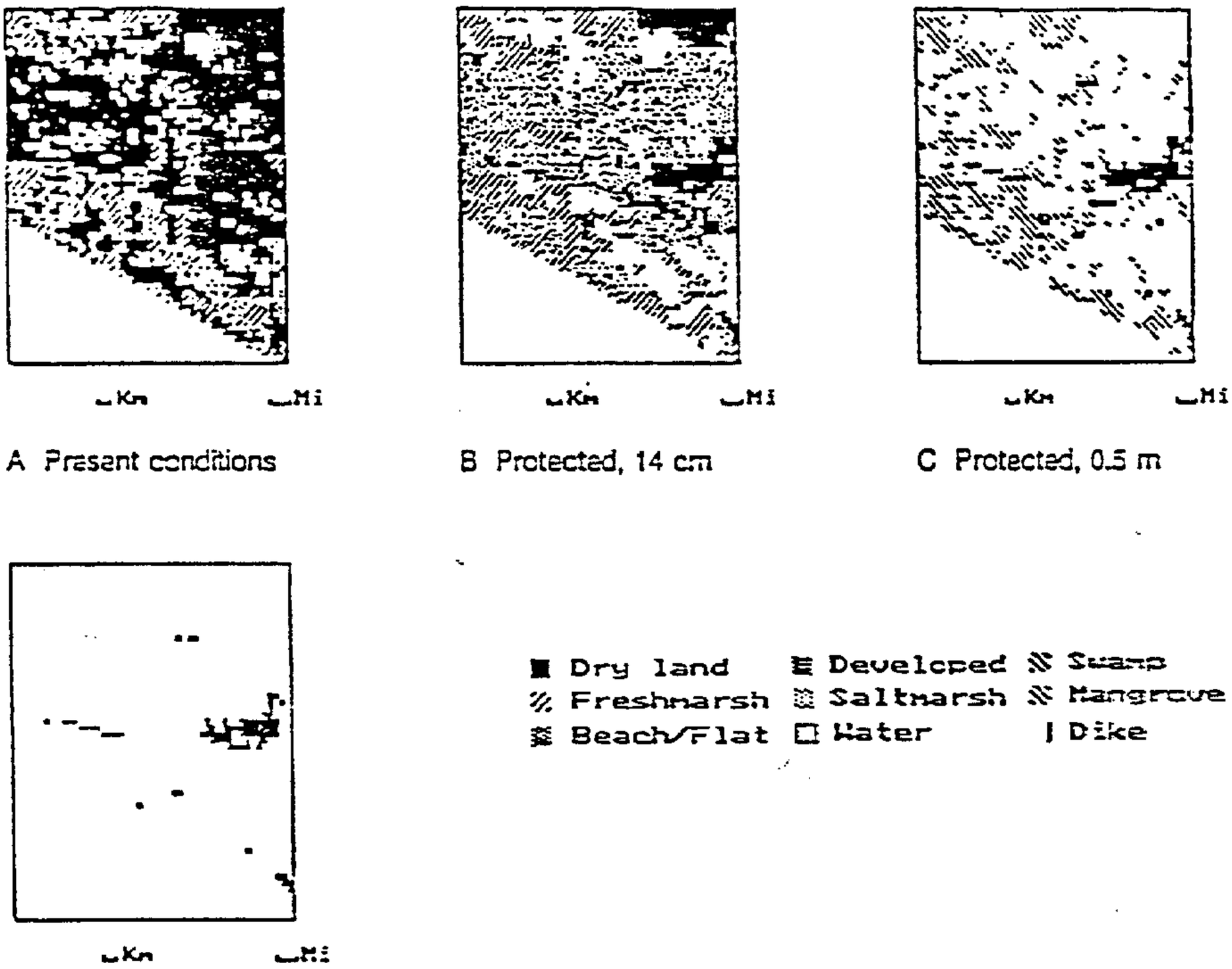
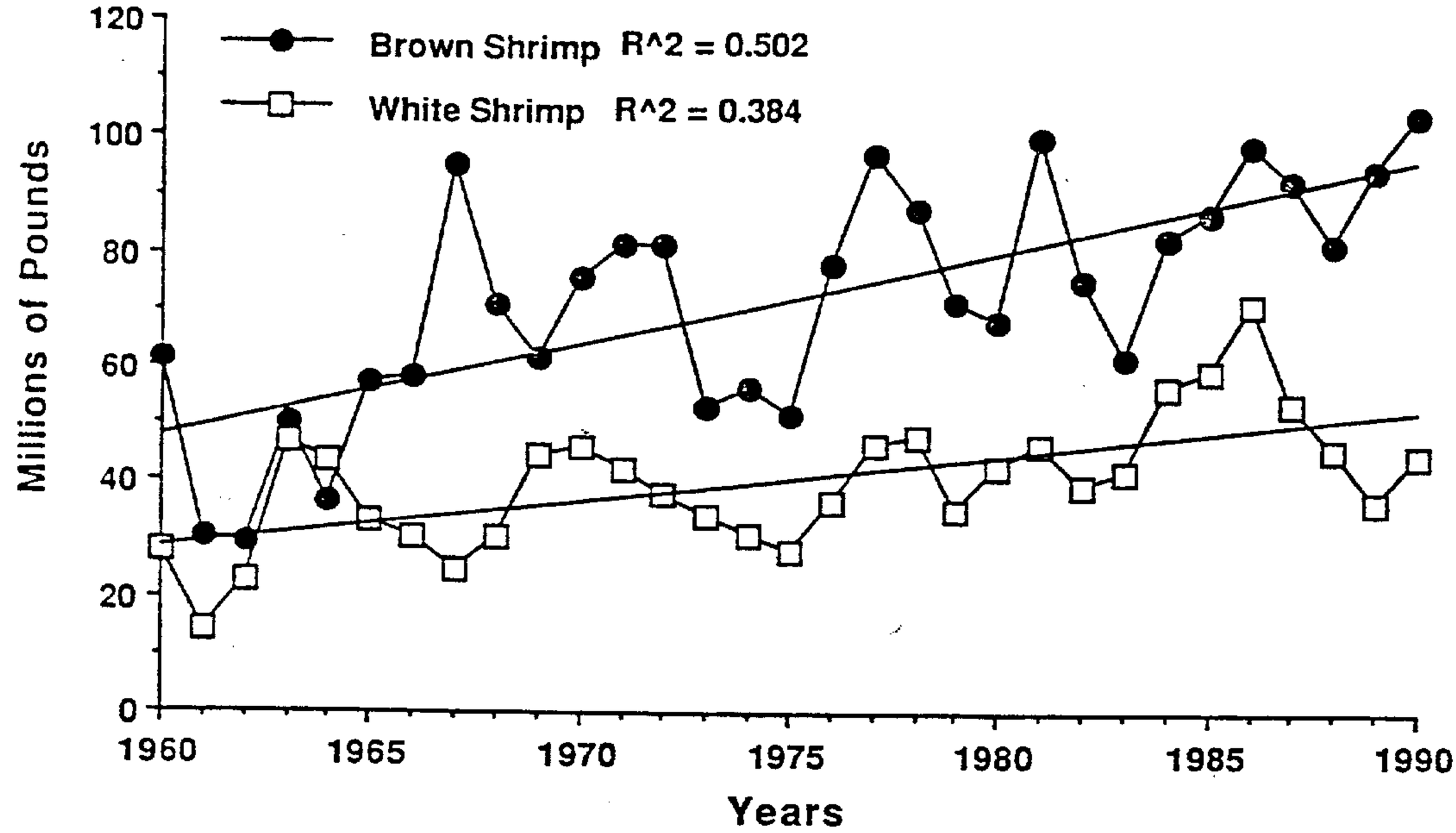


Figure 36. Predicted land loss and habitat change in Grand Chenier, Louisiana, over the next century under differing circumstances of sea level rise: (A) no change, (B) 14 cm, (C) 0.5 m, and (D) 1 m.

Has Fishery Production Increased in the NW Gulf of Mexico ?

HYPOTHESIS:

Fishery production has increased in the NW Gulf of Mexico due to marsh submergence.



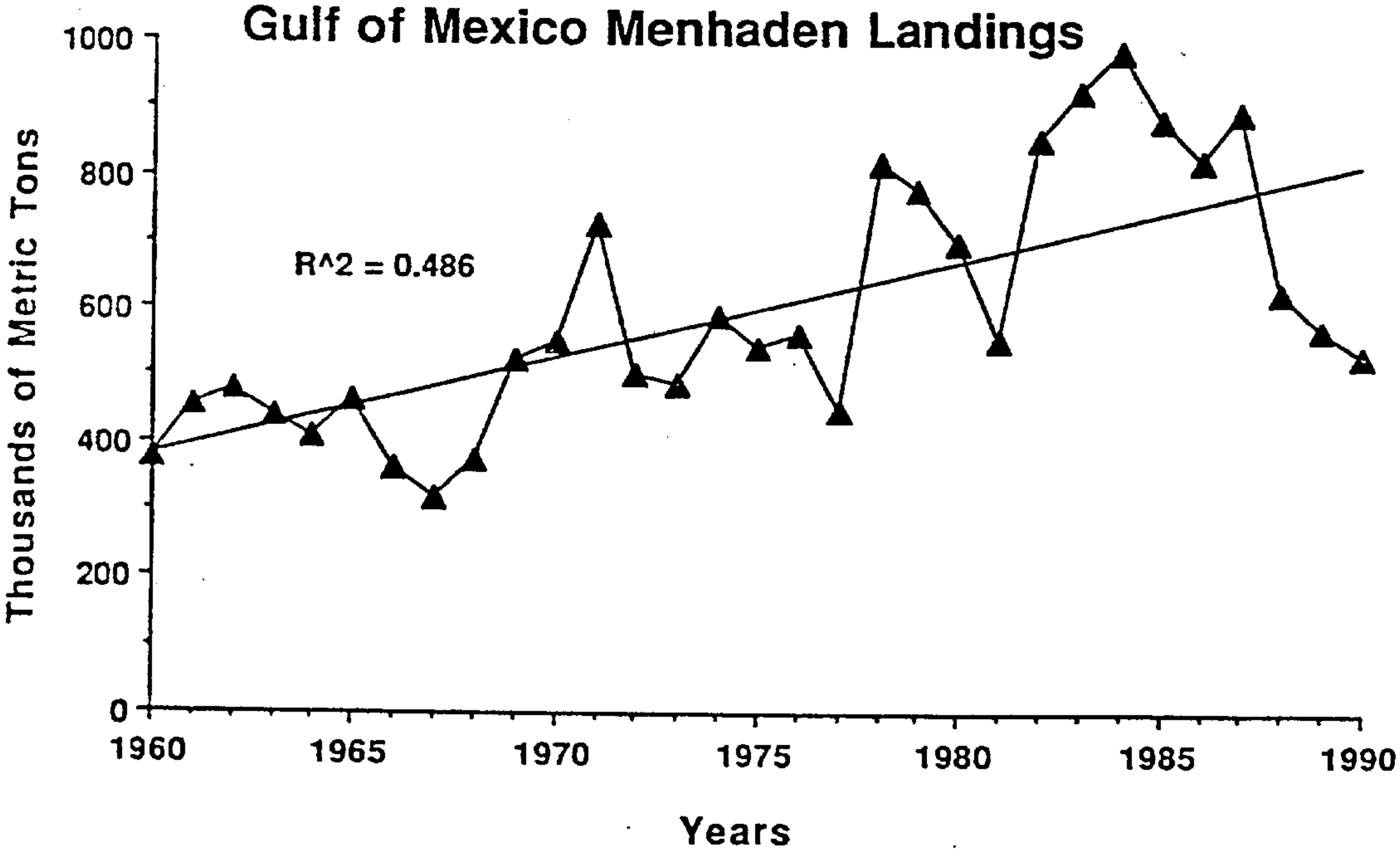


Figure 34. Gulf of Mexico white shrimp, brown shrimp and menhaden fishery landings from 1960 through 1990.

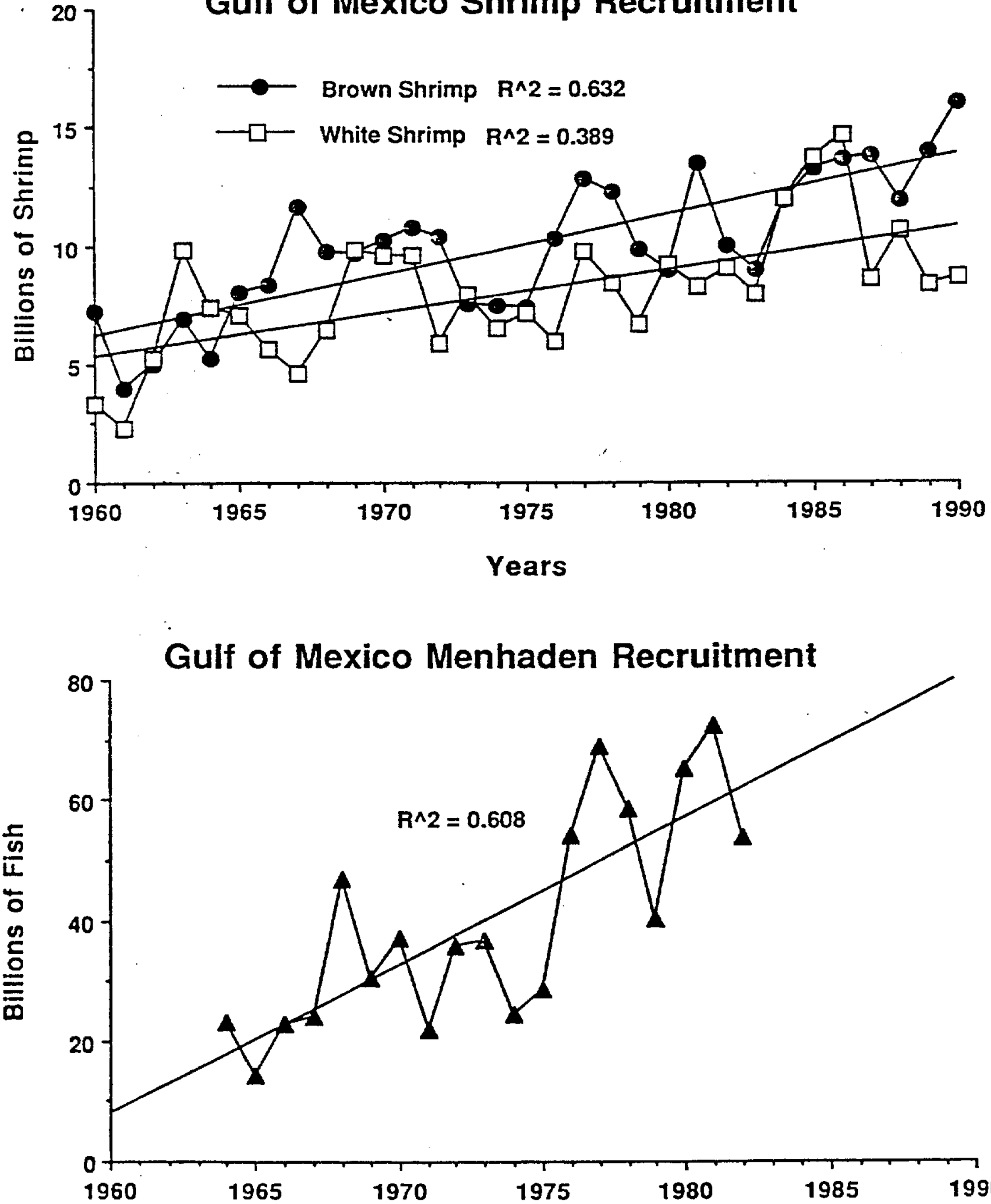


Figure 35. Recruitment of shrimp and menhaden in the Gulf of Mexico over the past three decades calculated by Virtual Population Analysis.

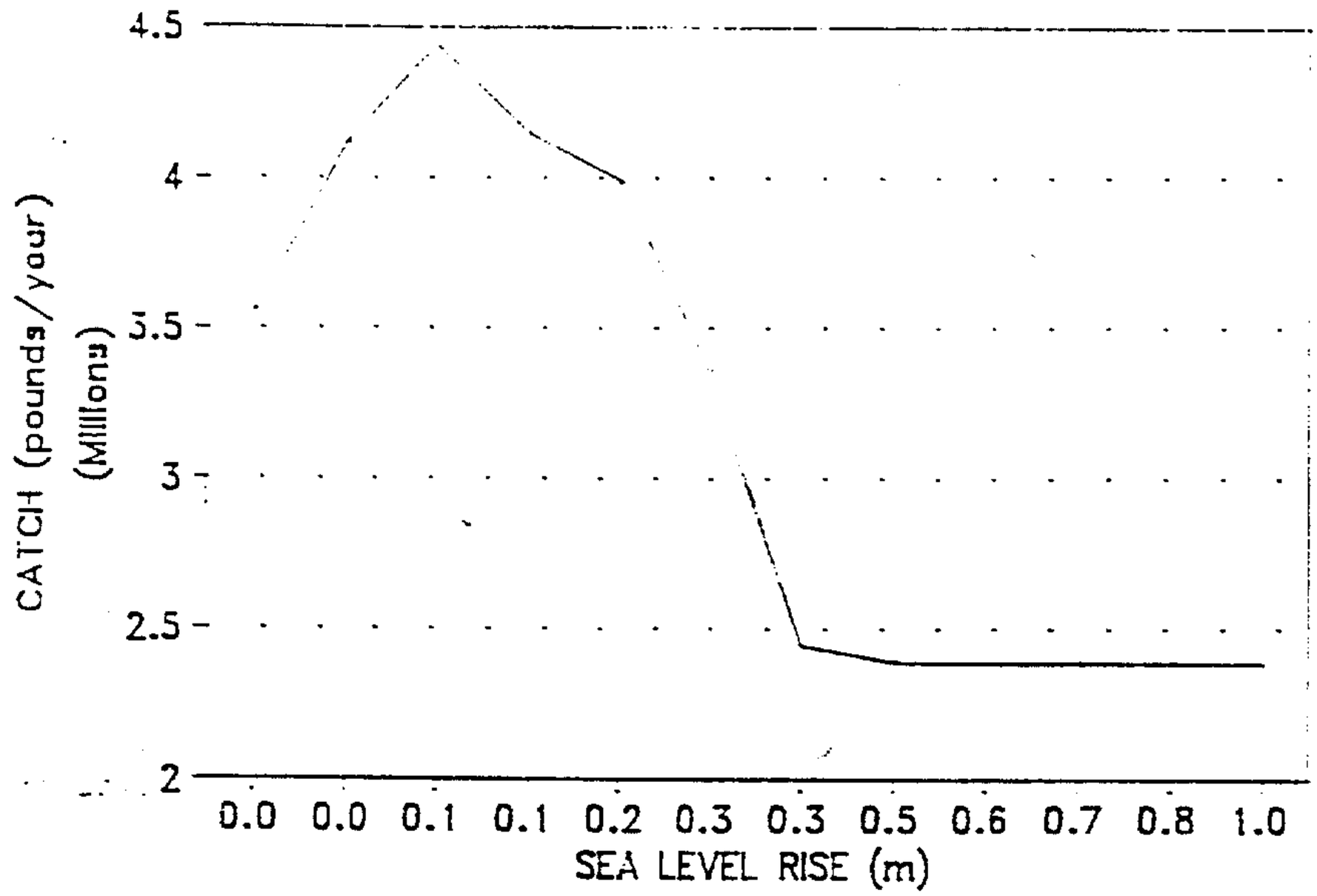


Figure 37. Predicted changes in shrimp landings of the Grand Chenier Louisiana area over the next century due to the effect of 1 m sea level rise.

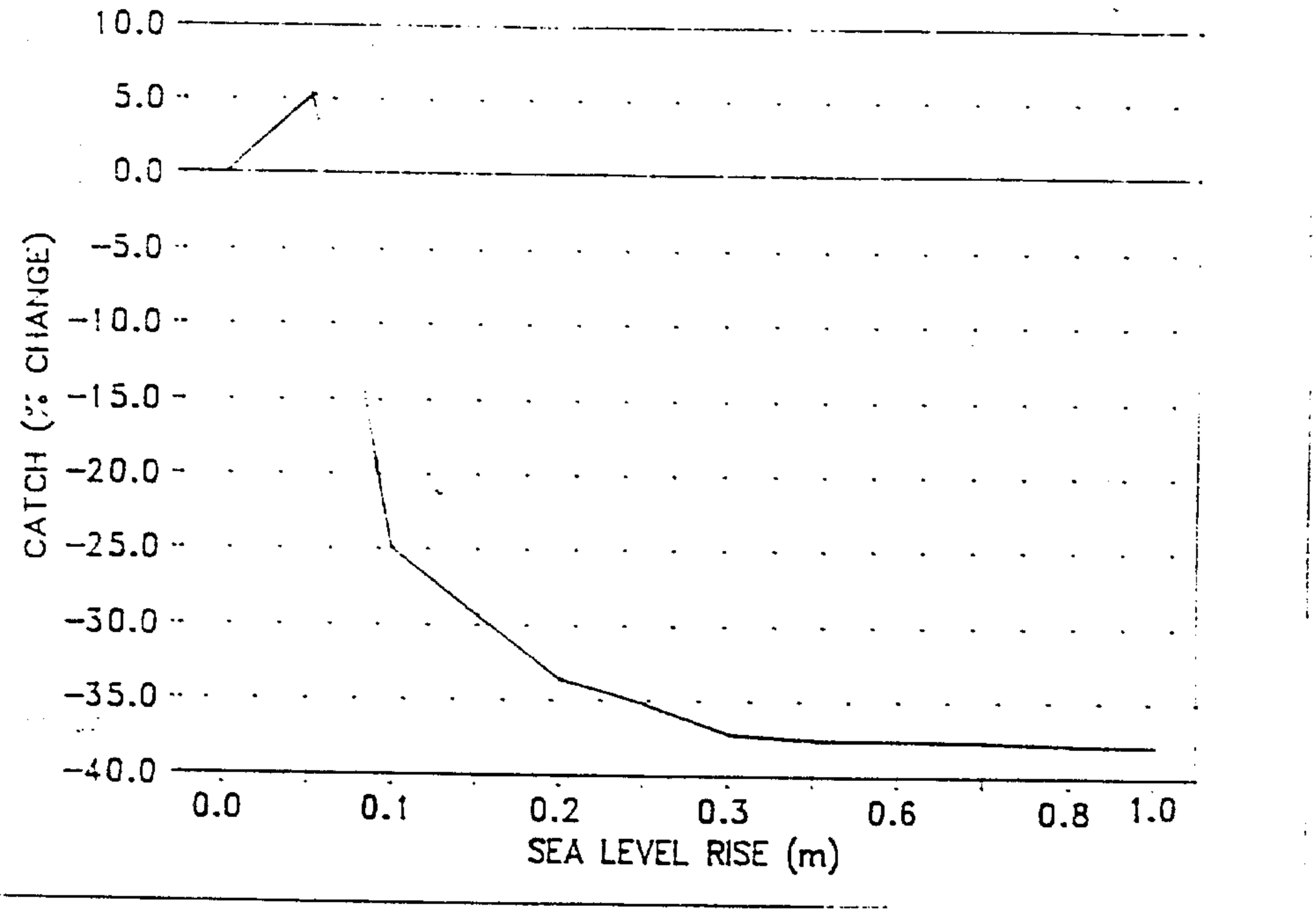


Figure 38. Predicted changes in brown shrimp landings of the Gulf of Mexico over the next century due to the effect of 1 m sea level rise.

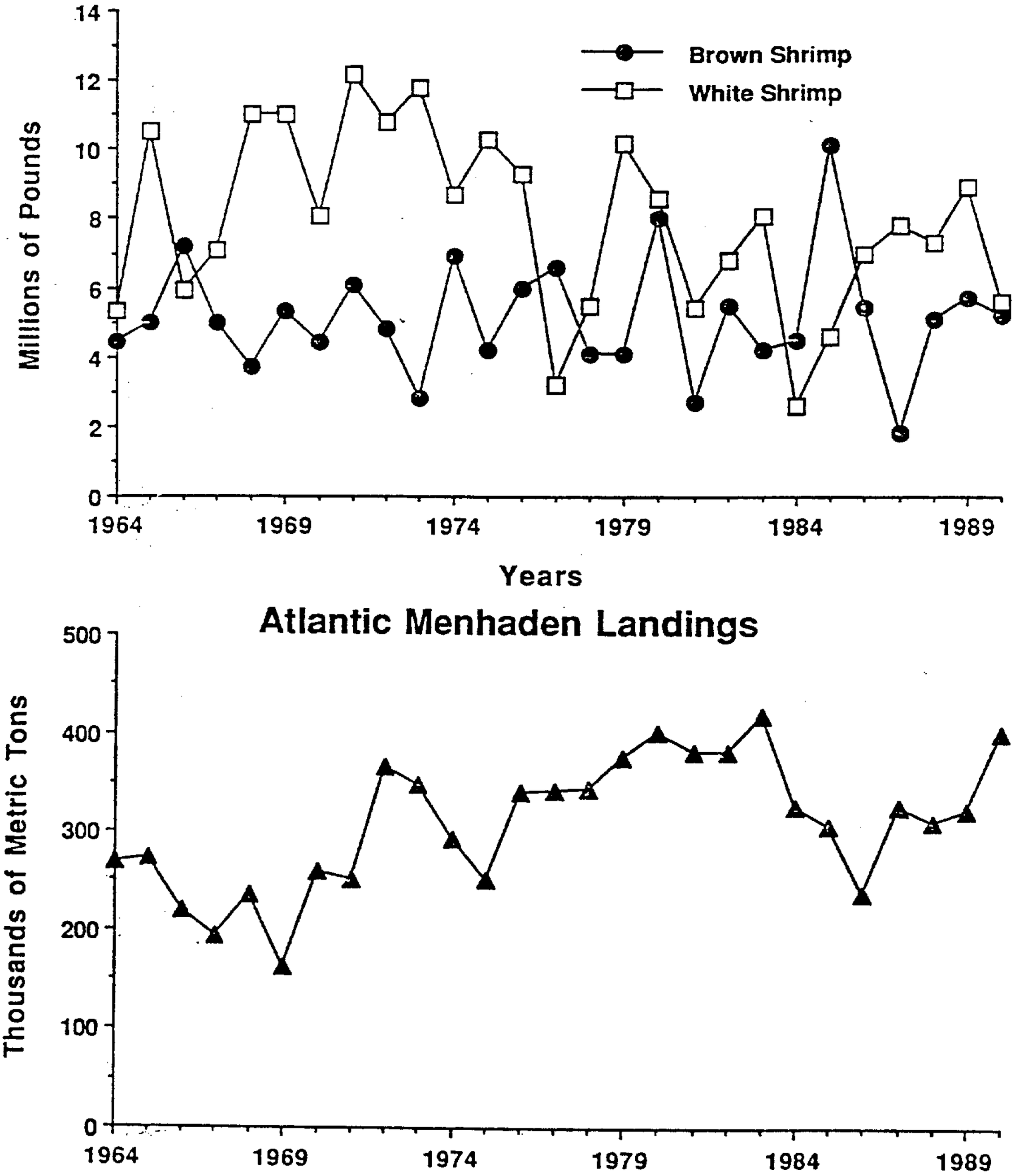


Figure 39. U.S. Southeast Atlantic coast white shrimp, brown shrimp and menhaden fishery landings from 1960 through 1990.

SUMMARY:

-- Subsidence effects may be used as a surrogate for sea level rise;

-- Fisheries changes related to sea level rise are predictable;

-- Effects of sea level rise on fisheries will depend on tides, geology and wetland types;

-- Wetland and fisheries responses can be modelled on basin, regional and global scales.

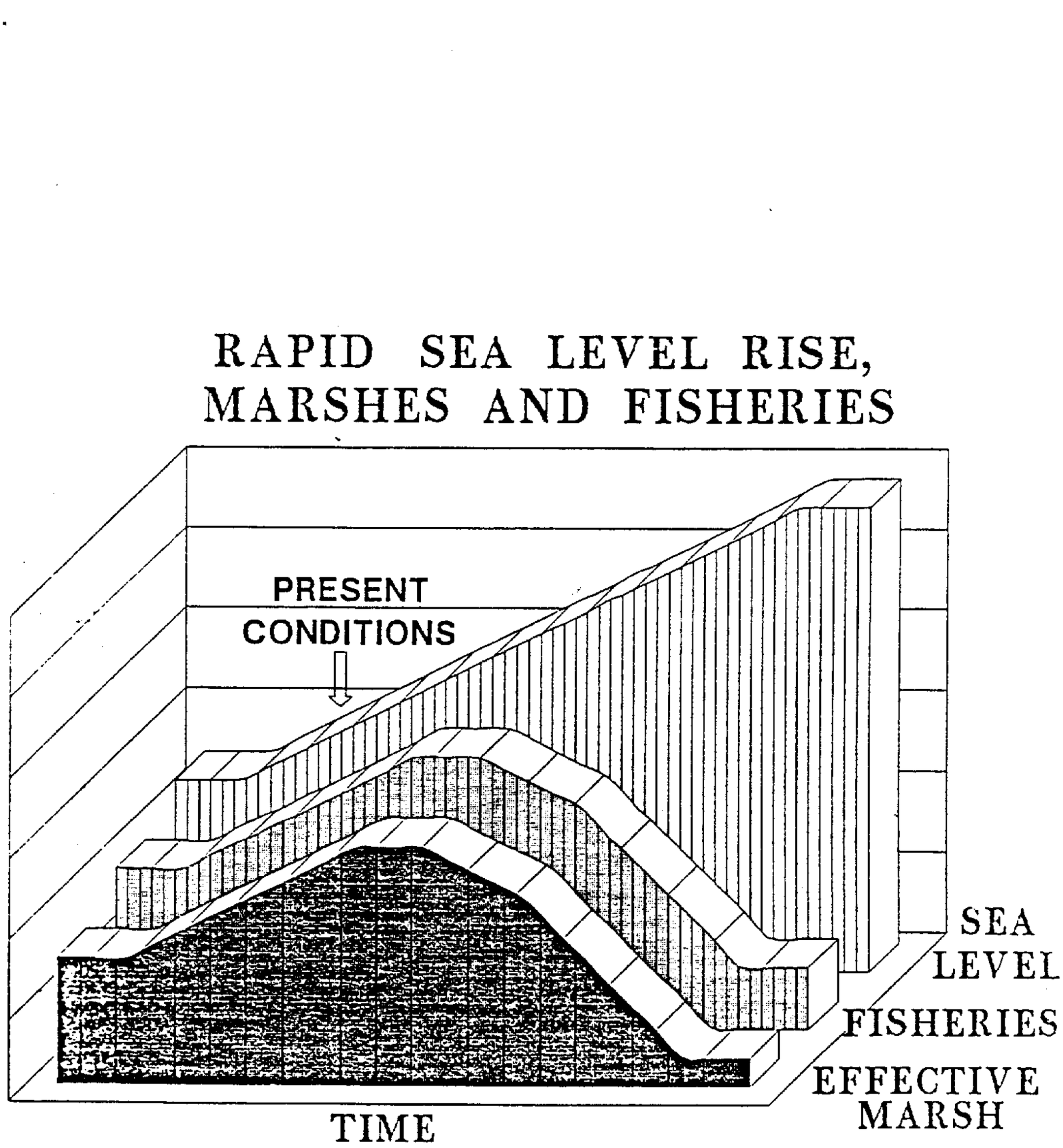


Figure 40. A conceptual model of responses of fisheries to changing marsh conditions due to accelerated sea level rise.

General Discussion
Global Warming - Dr. Roger Zimmerman

Fishery Productivity and Sea Level Rise
The general idea is that stable marsh is converted to unstable marsh, with unstable marsh being more productive.
Q: Hasn't sea level rise occurred in the past, with creation of new marsh?
A: Yes, but now, man-made barriers are preventing landward expansion of marshes. We have seen expanded fishery habitat (i.e production) in the past 30 years in the Northwestern Gulf of Mexico. One argument for this expansion is increased fishing effort and increased landings. Our argument for this, based on VPA's is increased recruitment, which could explain this increased effort.
Q: Are these data based on empirical data or based on a model?
A: Dr. Richard Park, by use of a model, has projected an approximate 50% loss of marshes given 1 meter sea level rise in the next century, most of that occurring in the Gulf of Mexico. He has put together a model for brown shrimp showing what we predicated, an initially increase in productivity, and then as marsh loss begins to have its effect, we see a decline in productively.
This is an initial model, and an area we are moving into; we would like to apply the models using empirical data.
Q: Has Dr. Park's work been published?
A: Some parts of it. We had a proposal with Dr. Park for global and climate change. It was one of the highest rated proposals, but it was not funded. We feel that this is something that we would like to pursue.
Q: Given it's obvious support, what do think is the most important point to focus on?
A: For the first time, we have empirical data to give us reasons to predict changes in fisheries, given the reasons for the changes, we can look for possible management tactics to elevate the decline in fisheries.
Q: Do we need other ways to quantify what is going to happen?
A: Yes, we need to refine our data.
Q: Could you use shrimp fishery data, in particular bycatch data over time, possibly look at predation?
A: We feel that inshore predation is much more significant than offshore predation.
We do not have inshore data. This is a multifaceted situation, but this is an area to examine.
Q: There are ways to quantify this to develop a better predictive model, etc. However, most of your staff is temporary, does this bother you? You have no intermediate grade-levels?
A: No we are not comfortable with this, budgetary constraints prevent this.
Q: You have ten years of marsh utilization data can you say anything about those data, as far as trends?
A: We need documentation of habitat change (for Jamaica Beach - study site) in order to convert our utilization data to productivity numbers.
Q: There is a question of rate, a continuous process, correlated with analyses that assumes that that's linear. You have a lot of other things going on, it seems like another focus would be to try to get at that through rate of increase in recruitment. That needs to be related to a set of factors to see if that rate makes sense in terms of the rates that you have.
A: Agree.
Q: In terms of individual plots, knowing that there are contaminants, do you do any chemical testing of these sites?
A: We do not, but there is the Galveston Bay National Estuarine Program that will supply these data.
Q: Do you think chemical contamination is a significant factor?
A: Upper Galveston Bay (i.e. entrance to the Houston Ship Channel) there could be real legitimate problems. In lower Galveston Bay, and in particular, our study site, no real problems evident.
Q: If given the opportunity to devote your time to one project, what would that be?
A: Area-wide and regional differences in value of habitat for fisheries.